WALLACE

Investigation of a Strauss

Trunnion Bascule Bridge

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INVESTIGATION OF A STRAUSS TRUNNION BASCULE BRIDGE

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I recommend that the thesis prepared under my supervision by EDWARD WALLACE entitled Investigations of a Strauss Trunnion Bascule Bridge be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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TABLE OF CONTENTS

INVESTIGATION OF A STRAUSS TRUNNION BASCULE BRIDGE

I. INTRODUCTION.

The heel-trunnion bascule bridge is the latest and most economical design of the Strauss Bascule Bridge Company. Fig. 1 shows a line diagram of a "Heel Trunnion" bascule bridge. The point T is the main trunnion, located at the intersection of the lower chord and the end post of the truss, about which the moving leaf pivots. It is a fixed pivotal point. The counterweight trunnion C, also a fixed pivotal point, is located at the apex of a fixed triangular tower, about which the counterweight frame and concrete counterweight pivot. The counterbalancing effect is applied to the moving leaf through the counterweight link P_1 P_2, connected to the truss and the counterweight frame by means of pins at either end.

It is the purpose of this thesis to investigate this type of bridge, and the author has selected, through the courtesty of the Strauss Bascule Bridge Company of Chicago, a through-truss heel-trunnion bascule bridge built over the Cuyahoga River for the Erie Railroad Company, at Cleveland, Ohio.

The specifications used are the American Railway Engineering and Maintenance of Way Association, 1906, supplemented by the Strauss Bascule and Concrete Bridge Company's specifications for this Bridge.

II. ASSUMPTIONS AND GENERAL FEATURES

The assumed conditions as stated in the following paragraphs, are those used by the Strauss Bascule Bridge Company in their design and are self explanatory. These conditions are as follows:

1. Relative to the dead load pier reaction in a Strauss Trunnion Bascule Bridge (Heel Trunnion Type) the following points should be noted:

   a. Whereas the moving leaf is at all times perfectly balanced, there is no dead load reaction at the front end.
   b. The weight of the entire structure is therefore carried by the two tower piers.

2. Disregarding, for the sake of simplicity, the weight of the counterweight link and the operating strut, the reactions are due to:

   a. The weight of the tower.
   b. The weight of the moving leaf.
   c. The weight of the counterweight including trusses and bracing.

The reactions due to the weight of the tower are vertical and constant.

The moving leaf and the counterweight are supported on the tower as on a carriage; they do not rest directly on the pier, and if the tower is properly designed, it takes care of all the horizontal forces, the horizontal component of the main trunnion reaction neutralizing the horizontal component of the counterweight trunnion reaction through the tower.

It follows that the pier reactions due to the weight of the moving leaf and the counterweight are vertical. Furthermore, they are constant during the opening or closing of the bridge.

3. Owing to the fact that the four pins, main trunnion, counterweight trunnion, and the first and second link pins are located in the corners of a parallelogram, the angular movements of the moving leaf and the counterweight are the same; and, as the weight of the moving leaf is as much smaller than that of the counterweight as the lever arm of the latter is smaller than that of the former, it follows that the center of gravity of the system as a whole is not disturbed during the operation of the bridge, and therefore the pier reaction cannot vary.

4. Since the pier reactions cannot vary, it can be seen that the dead load reaction on the main trunnion pier (disregarding the reaction due to the weight of the tower) is equal to the weight of

moving leaf and the dead load reaction on the counterweight trunnion pier equal to the counterweight.

5. If the bridge is opened to such an angle (about 90 degrees) that the center of gravity of the moving leaf falls directly over the main trunnion, then at the same time the center of gravity of the counterweight falls directly below the counterweight trunnion; the trunnion reactions have no horizontal components and it becomes evident that the two piers the one carries the moving leaf and the other the counterweight.

The following conclusions can be drawn from the conditions stated above:

1. That in a Strauss Trunnion Bascule Bridge (Heel Trunnion Type) the dead load pier reaction are vertical and constant.

2. That the dead load reaction on the rest pier is zero.

3. That the dead load reaction on the main trunnion pier is equal to the weight of the moving leaf plus part of the tower.

4. That the dead load reaction on the counterweight trunnion pier is equal to the weight of the counterweight plus part of the tower.

In the above conclusions the counterweight means the concrete counterweight, together with the counterweight trusses, bracing, etc., and the center of gravity of the counterweight means the center of gravity of this composite body.

Relative to the reaction on the main trunnion of the Strauss Bascule Bridge (Hell Trunnion Type) the following points should be noted:

1. The weight of the moving leaf, which is a vertical force passing through the center of gravity of the moving leaf.

2. The link stress (link pin reaction) which passes through the second link pin and which coincides in direction with the counterweight link, since this is pin connected at both ends and would not be in equilibrium under any other condition.

3. The main trunnion reaction. Since the bridge is balanced this third force must pass through he point of intersection of the two others.

This point of intersection falls near the center of the span and somewhat below the bottom chord and the dead load main trunnion reaction is therefore a force which passes through the trunnion and is directed towards the point of intersection (reaction) while the moving leaf butts against the trunnion, which is keyed

to the tower in a direction which is inclined slightly upward and towards the tower (action).

It follows that according to the design the base (or body) of the main trunnion bearing, which is riveted to the heel end of the bascule truss, will always bear against the trunnion which is keyed to the tower truss and that the cap on this bearing might therefore be omitted, if it were not for practical reasons (lubrication, etc.)

This is also shown by analyzing the stress in the truss members.

The dead load stresses in the four members intersecting at the hip point (2nd link pin), including the end post, are all tension.

Of the two members intersecting at the main trunnion the dead load stress in the end post is tension, as stated, while the dead load stress in the bottom chord member is compression and the resultant of these two forces is a force inclined slightly upward and acting away from the moving leaf against the tower (action which again produces a reaction from the tower, as described above).

The live load reaction on the trunnions and the live load stresses in the truss members are in no way different from those in an ordinary truss. The thrust of a train (braking load) coming from the trunnion end of the bridge, however, will tend to push the moving leaf away from the trunnion (that is, produce bearing on the cap of the trunnion bearing and tension in the cap bolts); but in all cases so far investigated, this force has not been sufficient to overcome the dead load action going in the opposite direction and it could in any event be properly cared for by making the cap sufficiently strong.

Specifications additional to Cooper's General Specifications for Steel Railroad Bridges and Viaducts, 1906, and covering features special to bascule bridges.

(a) Structural steel, pins, and cast steel for structural purposes (trunnion bearings, etc.):

Case 1. Bridge closed and subject to dead and live loads: Loads and unit stresses as for stationary structures, in accordance with Cooper's "General Specifications for Steel Railroad Bridges and Viaducts, 1906".

Case 2. Bridge moving:

Find the actual macimum stress in each member that will occur at any angle of the opening during the movement of the bridge, and apply allowable unit stresses equal to 5/6 of the dead load unit stresses for stationary structures. Neglect reversal of stress as this takes place slowly.

Wind Load: 15 lbs. per square foot of entire surface of moving leaf figured center to center of trusses.

Journal bearing on trunnions under motion:

1700 lbs per square inch.

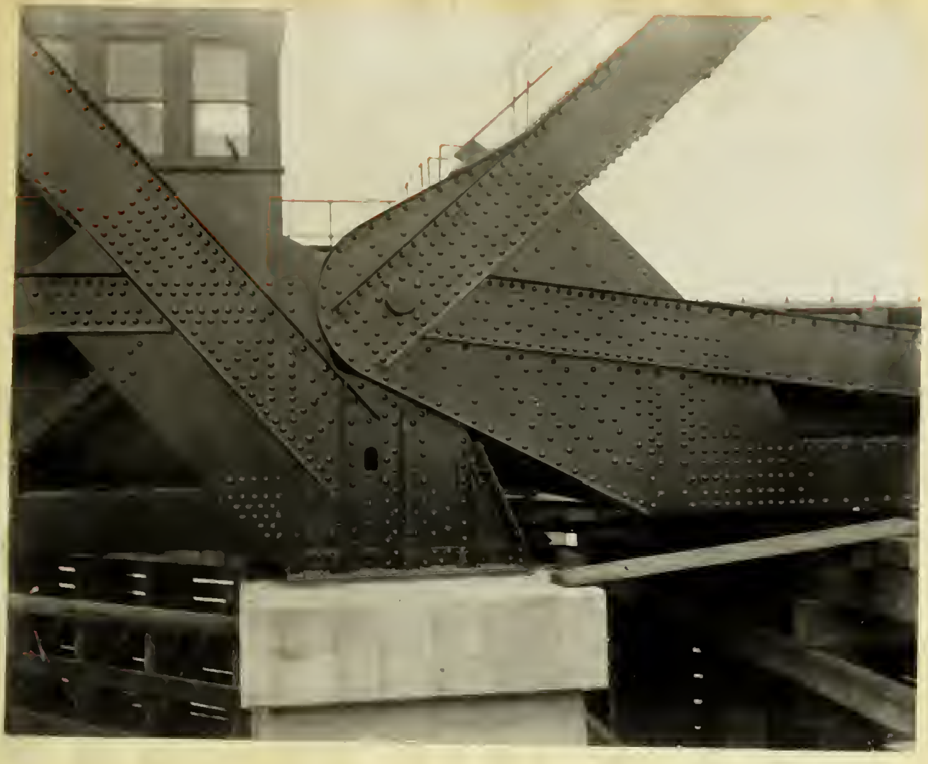
(b) Operating machinery.

Figure strength of operating machinery for a wind load of 15 lbs. per square foot as above, using the following unit stresses.

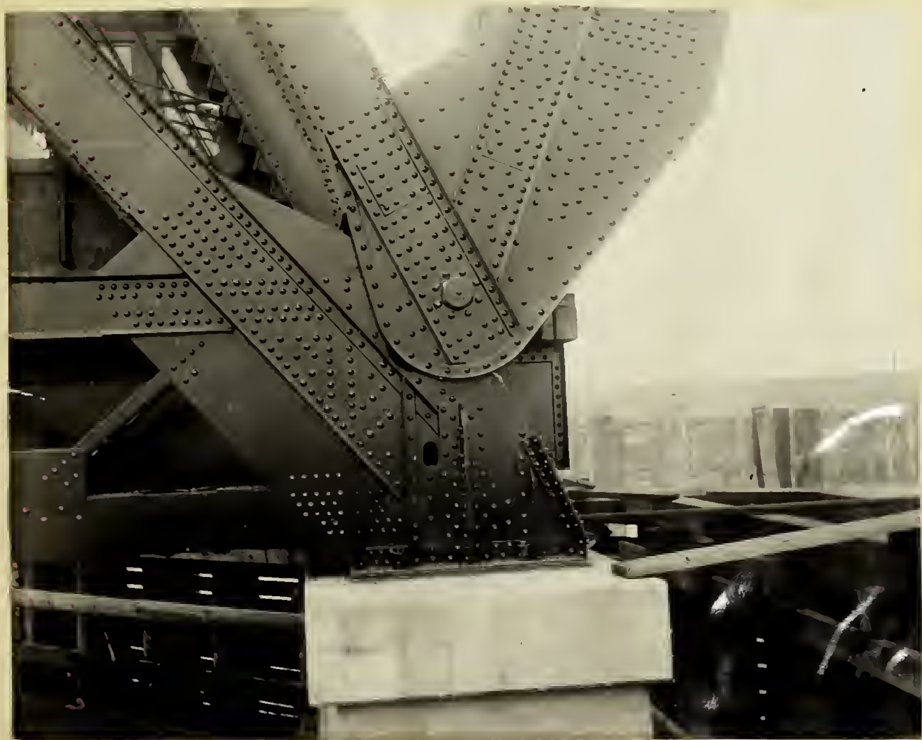
Slow speed shafting	16,000 lbs.	per	sq.	inch.	
High speed shafting	12,500 lbs.	"	"	"	
Slow speed gears	17,500	"	"	"	"
Medium speed gears	12,500	"	"	"	"
High speed gears	9,000	"	"	"	"

(c) Motors:-

Figure motors strong enough to operate the bridge against a wind pressure of 2 1/2 lbs. per square foot of moving leaf, as above, in 1 1/2 minutes; and also sufficient to operate bridge against a wind pressure of 10 lbs. per square foot.



Main Trunnion, Bridge Closed



Main Trunnion, Bridge Open

III. COMPUTATION OF WEIGHT.

The stresses and sections of the main members are shown in Plate I. From this plate and from information furnished by the Strauss Bascule Bridge Company, the weight of the complete structure was computed. The panel loading as shown in Fig. 1 was calculated by distributing the weight of the bracing between the trusses and the main members of the truss equally between their respective panel points.

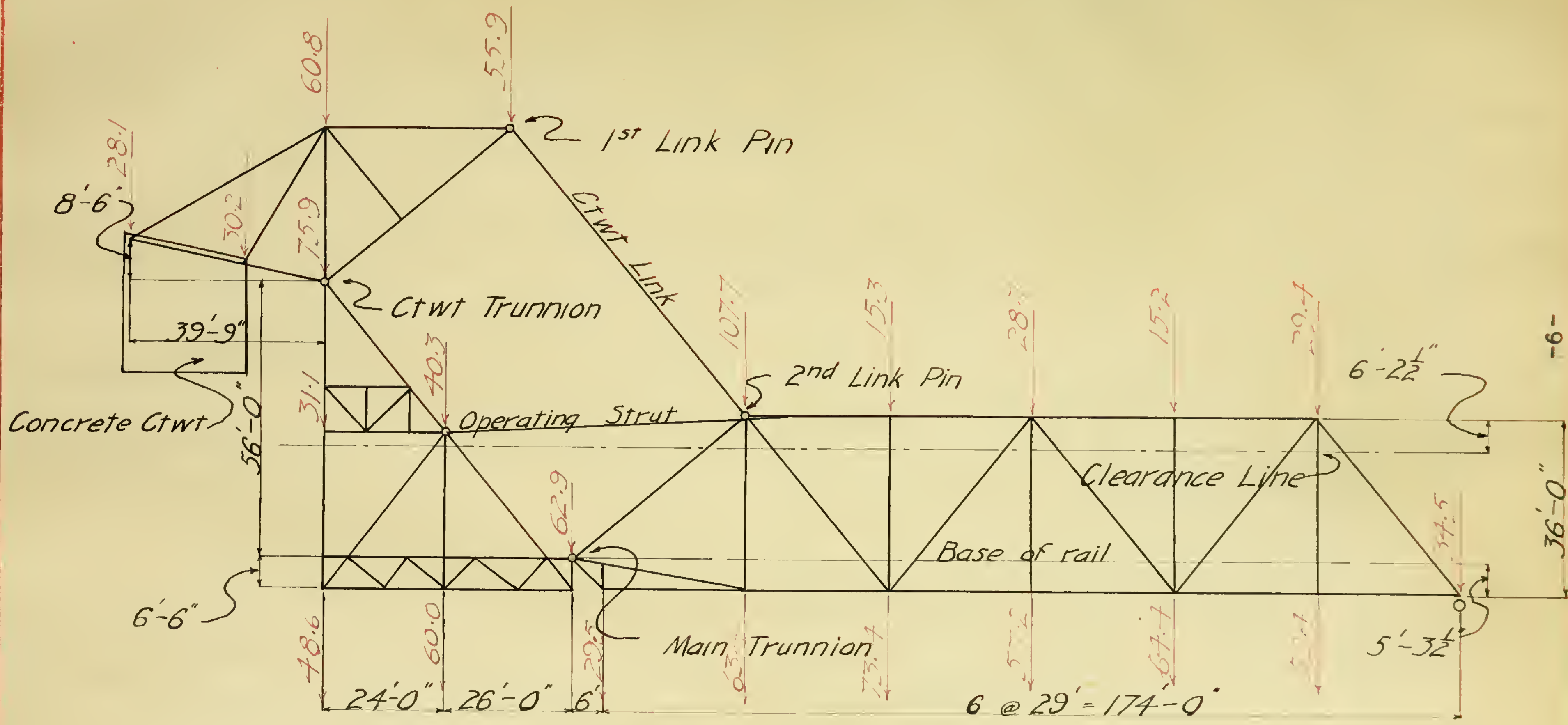


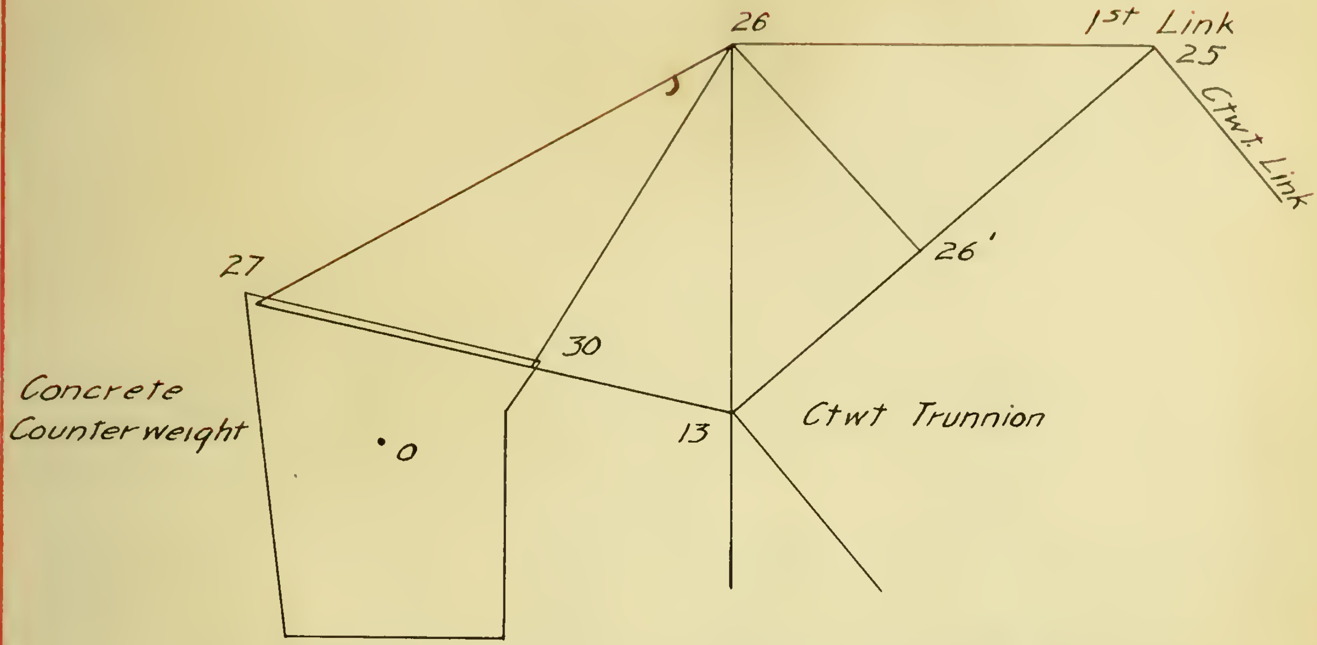
Fig. I General Dimensions and Panel Loads.

IV. COMPUTATION OF STRESSES

The stresses in this bridge are due to the dead load, live load, impact and wind. The dead load stresses in the moving leaf were figured under two conditions: bridge closed and bridge moving. The moving leaf was considered as a simple span in determining the live load stresses. The "Standard Specifications" were used in computing the impact stresses in the bascule truss for "bridge closed". The impact stresses in the bascule truss for "bridge moving" were figured on thirty-three and one-third per cent of the dead load stresses for "bridge moving".

A fixed set of rules were used in determining the maximum and minimum stresses in the counterweight truss. These rules were originally determined by the Strauss Bascule Bridge Company for a similar type of bridge.

These rules are as follows:



0 = Center of gravity of concrete counterweight.

25-26 Maximum tension when bridge is closed.
  0 when link stress is 0, i.e., 0-13 is vertical
  Maximum compression when bridge is open.

25-13 Maximum compression when bridge is closed
  0 when link stress is zero.
  Maximum tension when bridge is open.

26-27 Maximum tension when bridge is closed.
  Zero when 30-0 is vertical.
  Maximum compression when bridge is open.

26-30 Maximum tension when 27-0 is horizontal
  Zero when 27-0 is vertical.

26-13 Maximum compression when bridge is closed.

13-30 Maximum compression when bridge is closed
  Zero when 0-26 is vertical.
  Maximum tension when bridge is open.

30-27 Maximum compression when bridge is closed.
  Maximum tension when bridge is open.

Tables 1 and 11 give the stresses and sections in the counterweight and main trusses.

TABLE I
STRESSES & SECTIONS IN CTWT. TRUSS

Member	Max Stress		Imp $33\frac{1}{3}\%$		Total		Sections
	+	−	+	−	+	−	
25-26	1390	0	463		1853		4 Pls 32"x$\frac{3}{4}$" 4 Ls 6"x4"x$\frac{3}{4}$" 2 Pls. 24"x$\frac{1}{2}$"
26-27	1112	0	370		1482		do. 4 Ls 6"x4"x$\frac{5}{8}$"
26-30	1500	0	500		2000		4 Pls. 32"x$\frac{3}{4}$" 4 Ls 6"x4"x$\frac{3}{4}$"
25-13	0	1050		350		1400	4 Pls. 34"x$\frac{3}{4}$" 4 Ls 6"x4"x$\frac{5}{8}$"
26-13	0	1375		458		1833	do. 4 Ls 6"x4"x$\frac{13}{16}$"
27-30	812	1000	270	333	1082	1333	do. 4 Ls 6"x4"x$\frac{3}{4}$"
30-13		575		192		767	do. 4 Ls 6"x4"x$\frac{3}{4}$" 2 Pls. 26"x$\frac{5}{8}$"
26-26'	0	0		0		0	4 Ls 6"x4"x$\frac{3}{4}$"

Note: Plus (+) denotes tension. Minus (−) denotes compression
All stresses are in 1000 lb.

TABLE II
STRESSES AND SECTIONS IN MAIN TRUSS

	Member	Case I Bridge Closed D.L.	L.L. +	L.L. −	Impact +	Impact −	Total +	Total −	Case II Br. Moving D.L.	Imp. $33\frac{1}{3}\%$	Total	Sections
TOP CHORD	0-1	+44.3		607		289		887	+44.3	+14.8	+59.1	2 Pls. $28'' \times \frac{3}{4}''$ $2L^s$ $6 \times 4'' \times \frac{15}{16}''$ $2L^s$ $6'' \times 4'' \times \frac{7}{16}''$ 1 Cov. Pl. $34'' \times \frac{3}{8}''$
	1-3-5	+113.5		594		278		852	+113.5	+37.8	+151.3	2 Pls. $28'' \times \frac{3}{4}''$ $4L^s$ $6'' \times 4'' \times \frac{9}{16}''$
	5-7-9	+529.0		622		290		812	+529	+176	+705	do. do.
	9-12	+126.3		582		279		840	+126.3	42.1	+168.4	do. $2L^s$ $6'' \times 4'' \times \frac{3}{8}''$ $2L^s$ $6'' \times 4'' \times \frac{7}{8}''$ 1 Cor. Pl. $34'' \times \frac{3}{8}''$
	11-12	+40.0	263		218		521		+40	+13.3	+53.3	1 Pl. $20\frac{1}{2}'' \times \frac{3}{4}''$ $4L^s$ $6'' \times 6'' \times \frac{1}{2}''$
BOT. CHORD	0-2-4	-27.8	381		182		559		-27.8	-9.3	-37.1	2 Pls. $24'' \times \frac{9}{16}''$ $4L^s$ $4'' \times 4'' \times \frac{9}{16}''$
	4-6-8	-263.6	683		333		1020		-263.6	-87.9	-351.5	4 Pls. $24'' \times \frac{9}{16}''$ $4L^s$ $4'' \times 4'' \times \frac{3}{4}''$
	8-10	-773.6	437		201			900	-773.6	-257.8	-1031.4	do. do.
	10-12	-786.0	405		197			915	-786.0	-262.0	-1048.0	2 Pls. $24'' \times \frac{3}{4}''$ $4L^s$ $4'' \times 4'' \times \frac{3}{4}''$ 2 Pls. $24'' \times \frac{1}{2}''$
VERTICALS	1-2	+52.4	210.9		152.1		415		+52.4	+17.5	+69.9	$4L^s$ $7'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ 1 Pl. $22'' \times \frac{1}{2}''$
	3-4	-15.2	0			0		15.2	-15.2	-5.06	-20.26	$4L^s$ $7'' \times 3\frac{1}{2}'' \times \frac{7}{16}''$
	5-6	+57.2	210.9		152.1		420		+57.2	+19.1	+76.3	$4L^s$ $7'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ 1 Pl. $22'' \times \frac{1}{2}''$
	7-8	-15.3	0			0		15.3	-15.3	-5.1	-20.4	$4L^s$ $7'' \times 3\frac{1}{2}'' \times \frac{7}{16}''$
	9-10	+206.8	194		140		540		+26.8	+89.3	+116.1	$4L^s$ $7'' \times 3\frac{1}{2}'' \times \frac{5}{8}''$ 1 Pl. $22'' \times \frac{9}{16}''$
	11-11'	0		0		0		0	0	0	0	$4L^s$ $7'' \times 3\frac{1}{2}'' \times \frac{7}{16}''$ 1 Pl. $22'' \times \frac{7}{16}''$
DIAGONALS	1-4	-136.8	419	29.9	220	24	617		-136.8	-45.6	-182.4	2 Pls. $22'' \times \frac{11}{16}''$ $4L^s$ $4'' \times 4'' \times \frac{3}{4}''$
	4-5	+239.0	102.5	25.2	71	150	413		+239.0	+79.6	+318.6	2 Pls. $22'' \times \frac{9}{16}''$ $4L^s$ $4'' \times 4'' \times \frac{9}{16}''$
	5-8	-349.0	12.0	222	83	133		704	-349.0	-116.3	-465.3	4 Pls. $22'' \times \frac{7}{16}''$ $4L^s$ $4'' \times 4'' \times \frac{3}{4}''$
	8-9	+463	377	42.0	191	33	1031		+463	+154.3	+617.3	2 Pls. $22'' \times \frac{5}{8}''$ $4L^s$ $4'' \times 4'' \times \frac{5}{8}''$ 2 Pls. $22'' \times \frac{11}{16}''$
	10-11	+28.9	198		164		391		+28.9	+9.6	+38.5	2 Pls. $16'' \times \frac{1}{2}''$ $4L^s$ $4'' \times 4'' \times \frac{1}{2}''$

Note: Plus (+) denotes tension. Minus (−) denotes compression.
All stresses are given in 1000 lb.

V. Investigation

It is the purpose in this chapter to investigate the main members of the bascule truss. The table below shows the efficiencies of all the members of the moving leaf.

TABLE III
EFFICIENCIES OF MEMBERS IN MAIN TRUSS

Member	Gross Area □"	Net Area □"	Req'd Area □"	$\frac{l}{r}$	Efficiency
0-1	80·1		71·9	52·2	103·5
1-3-5	63·2		63·2	35·5	100·0
5-7-9	63·2		60·2	35·5	105·0
9-12	77·9		68·8	54·3	113·1
11-12	38·4	32·9	32·6		101·0
0-2-4	43·7	34·8	34·9		99·5
4-6-8	75·8	60·8	63·8		95·5
8-10	75·8		69·2	42·9	109·5
10-12	81·7		73·6	51·2	111·0
1-2	31·0	26·0	25·9		100·5
3-4	17·6		19·5	78·5	90·0
5-6	31·0	26·0	26·3		99·0
7-8	17·6		19·5	78·5	90·0
9-10	37·1	31·0	33·8		91·8
11-11'	27·2				
1-4	52·0	40·5	38·6		105·0
4-5	41·5	32·6	25·8		126·0
5-8	60·3		63·5	70·2	95·0
8-9	76·2	60·6	64·3		94·3
10-11	31·0	24·0	24·4		98·4

VI. CONCLUSION

In looking over the diagram of the bascule bridge it will be seen that the distribution of the loading is fairly uniform. The stresses that were figured are a little larger than those originally designed for by the Strauss Bascule Bridge Company. The difference between the stresses is due to the approximate methods used by the designers in computing the dead load. The investigation was made only of the main members of the bascule truss. Very favorable efficiencies were computed which can be found in the preceding chapter. The results in general show that the bridge was well designed.